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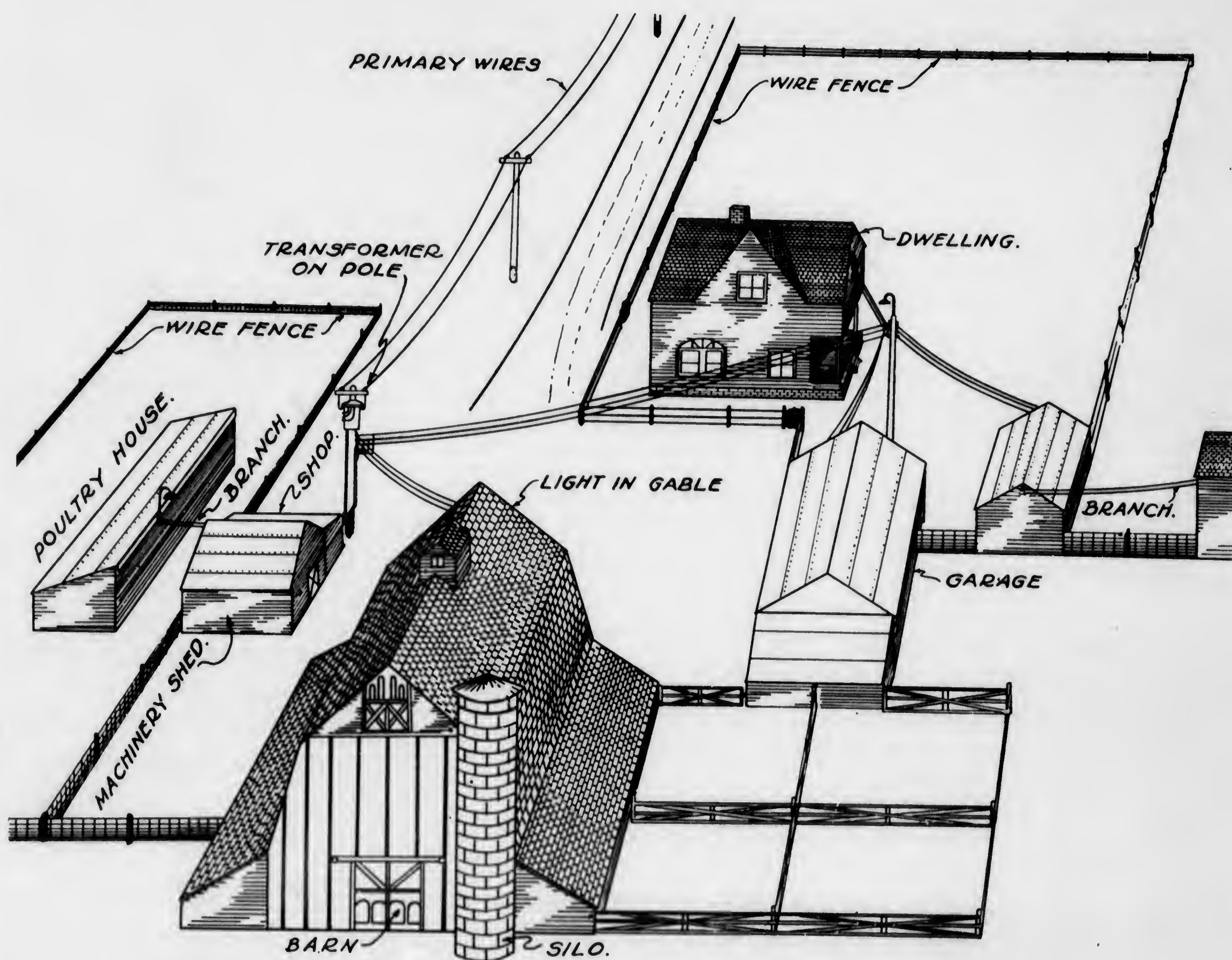
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Problems In the Application of Electricity In the Home and On the Farm

For Use in the Course "Farm Mechanics" as outlined in Circular 7,
Agricultural Series No. 5, by the Vocational Division,
Pennsylvania Department of Public Instruction, Harrisburg, Pa.



CIRCULAR I
PUBLISHED AUGUST, 1935

by the
PENNSYLVANIA JOINT COMMITTEE ON RURAL ELECTRIFICATION
JOHN M. MCKEE, EXECUTIVE SECRETARY
HARRISBURG, PENNA.

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INTRODUCTION

There are now 179,078 customers on rural electric lines in Pennsylvania of whom 45,374 are farmers. Under the Pennsylvania Plan for extending service, customers have been added on all rural lines during the past eight years at the rate of 43 for each working day. The leaders in Vocational Agricultural Education in Pennsylvania early sensed the importance of the training of farm boys and girls in the characteristics and applications of electricity. Accordingly, they included in their Farm Mechanics Course, Circular 7 Agricultural Series No. 5, an enterprise on Farm Electricity. Experience has shown a need of material in readily usable form for this enterprise.

To meet this need, the Department of Public Instruction, Harrisburg, the Departments of Agricultural Engineering and Rural Education of the Pennsylvania State College and the Joint Committee on Rural Electrification have cooperated in making this material available. The actual preparation was largely done by Mr. D. L. Sprague of the Department of Agricultural Engineering and Mr. G. Floyd Dye, Supervisor of Agriculture, Imperial, Pa. Upon request, representatives of the West Penn Power Company assisted with technical details and drawings.

The aim has been to prepare problems in the form of questions, information and applications; first, as an aid to the pupil in working out practical jobs under the farm electricity enterprise, and second, to create interest and further study of the references. It is desirable that as many as possible of the references be secured. These problems are prepared in preliminary form with the request that as vocational teachers use them, suggestions for improvement be offered for a revised issue.

The Pennsylvania Joint Committee on Rural Electrification, a voluntary body composed of representatives of the farm organizations and the electric companies is organized to extend and improve the use of electricity in rural districts. This Committee upon request is issuing this circular as an aid to the rural electrification program in Pennsylvania. A general understanding of the characteristics of electricity, how to make minor additions or changes to the wiring system and how to locate trouble and repair equipment will add to the convenience and economy of electric service on the farms and in the homes of Pennsylvania.

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PROBLEM I

GENERAL INFORMATION ELECTRICAL TERMS, DEFINITIONS, AND REFERENCES

Related Questions for Discussion

1. What is electricity?
2. What is the unit for expressing electrical pressure?
3. What is the unit for expressing rate of current flow?
4. How is electrical energy measured?
5. How is electricity transmitted from one point to another?
6. What materials are the best conductors and insulators?
7. What is electrical resistance?
8. In what unit is resistance measured?
9. What is the unit for measuring electrical power?
10. What are the units for measuring electrical energy?
11. What is meant by Ohm's law?
12. What instruments are used in measuring electrical units?
13. What uses are made of electrical energy?
14. What are the advantages of electricity for light, heat and power?
15. What are the mechanical and heat equivalents of electrical units?
16. What is direct current?
17. What is alternating current?
18. What is meant by 60 cycle alternating current?
19. How can the energy consumption of a lamp or any other equipment be estimated for a day, month, or year?
20. What information is given on the name plates of electrical equipment?

INFORMATION

Electricity may be conceived as being composed of infinitely small particles called electrons. These constitute the essential parts of the atom which make up all known substances. The flow of these electrons through an electrical circuit is analogous to the flow of water through a pipe. Electricity which flows continuously in one direction through an electric circuit is known as

direct current (d.c.). Any path through which electricity will flow is an electrical circuit.

The amount of electricity, or electric current, flowing through a circuit is measured in "amperes." This is a unit of the rate of flow and may be likened to gallons of water per minute or cubic feet per second.

Like water flowing through a pipe, electricity will not flow through a circuit unless it is under pressure. Electrical pressure is known as potential or electro-motive force (e.m.f.), the unit of measurement being the "volt."

In alternating currents (a.c.), the flow of electricity is reversed in direction at regular intervals as it passes through the circuit. In such a circuit the electrical pressure or voltage is continually changing. The voltage of an alternating current is taken to be the average voltage occurring and not the maximum values reached. One complete voltage change from zero to a maximum positive value and back to zero, then to a maximum negative value and back to the original value of zero is known as one cycle. By 60-cycle alternating current is meant that 60 of these complete changes occur each second. Alternating current is the type usually generated by electric companies.

Power expresses the rate at which work is done. The mechanical power unit is the horsepower and is equivalent to lifting 33,000 pounds one foot in one minute. An electric current does work at a rate proportional to its current strength and to the voltage at which it operates in the circuit. The unit of electrical power is the "watt." The electrical power or "watts" flowing in a circuit equals the product of the current in amperes and the pressure in volts, or $P = E \times I$, where $P =$ watts, $E =$ volts, and $I =$ amperes.

One watt is equivalent to $\frac{1}{746}$ of a horse power. As this is a rather small unit of power the "kilowatt" is often used when speaking of the power required by electrical equipment. The "kilowatt" equals 1000 watts.

Energy is the ability to do work. It is generally expressed in terms of the rate at which the work is done and the time used in doing it. Since the rate of doing work is power, energy is equal to the product of power and time. For example, if a 2 horse power motor must operate a pump $1\frac{1}{2}$ hours to fill a water tank, the mechanical energy represented by this work is 2 horse power multiplied by $1\frac{1}{2}$ hours, or 3 "horse-power-hours." Likewise, electrical energy is measured in "watt-hours" or in the larger units, "kilowatt-hours." For example, if the electrical power input to the above motor is 2 kilowatts, the amount of electrical energy required to pump the water will be 2 kilowatts multiplied by $1\frac{1}{2}$ hours, or 3 "kilowatt-hours."

An electric current will flow to some extent through any material but it passes more readily through some than others. It flows easily through materials such as copper, aluminum, silver and others which are called electric "conductors." Materials which allow almost no electricity to pass through them, such as cotton, silk, glass, rubber, and porcelain are called insulators. The resistance offered by any conductor to the flow of electricity can be measured, the unit of resistance being the "ohm." An electrical pressure, or voltage of 1 volt will force a current of one ampere to flow through a resistance of 1 ohm. The mathematical statements of this relationship are:

$I = \frac{E}{R}$, $E = IR$, and $R = \frac{E}{I}$, where I is the current in amperes; E is the electro-motive force in volts; and R is the resistance in ohms. This relationship is known as "OHM'S LAW."

The mathematical relationship between power (watts), current (amperes) and voltage (volts) is: $P = IE$ where $P =$ watts. This relationship and Ohm's law hold true for all direct current circuits, but owing to certain characteristics of alternating current circuits they can not always be directly applied to them. The uses of these relationships are illustrated by the following problems:

EXAMPLE 1. A 220-volt water heating element has a resistance of 45.8 ohms. What current in amperes will be required? SOLUTION: Using the relationship $I = \frac{E}{R}$ the current (I) is found to equal $\frac{220}{45.8}$, or 4.54 amperes.

EXAMPLE 2. What will be the wattage of the heating element? SOLUTION: Using the relationship $P = IE$ the wattage (P) is found to be 4.54×220 or 1000 watts.

EXAMPLE 3. If the water heater operates $2\frac{1}{2}$ hours daily, how many kilowatt-hours of electrical energy will be consumed per day? SOLUTION: Electrical power is being supplied at the rate of 1000 watts, or 1 kilowatt. For an operating period of $2\frac{1}{2}$ hours, 1 kilowatt $\times 2\frac{1}{2}$ hours, or $2\frac{1}{2}$ kilowatt-hours of electrical energy will be utilized.

DEFINITIONS

AMPERE (unit of flow) the amount of electricity which will deposit 0.001118 grams of silver in one second from a standard silver nitrate solution.

VOLT (Unit of electro-motive force) - the electro-motive force (e.m.f. generated by a standard cell or battery constructed in a standardized way of carefully specified materials.

WATT (unit of power) - the product of volts and amperes, and represents the rate of doing work.

WATT-HOUR (unit of energy) - the product of watts and time in hours.

OHM (unit of resistance) - the resistance offered to any unvarying electric current by a column of mercury at the temperature of melting ice, 106.3 centimeters long and having a cross sectional area of 1 square millimeter.

FOOT-POUND (unit of work) - a force of one pound acting through a distance of one foot (force in pounds $\times$ distance in feet).

HORSE POWER (unit of power) - 33,000 foot-pounds per minute.

HORSE-POWER-HOUR (unit of energy) - one horse power developed for one hour (1 horse-power-hour $=$ 1,900,000 foot-pounds).

BRITISH THERMAL UNIT (Unit of heat) - the heat required to raise 1 pound of water 1° F.

GROUND OR GROUNDING - A safety device which is an electrically tight connection to the earth, to dispose of surplus or overflow electricity by allowing it to leak to ground. This is usually composed of a wire, with soldered joints, connected to either a well earthed and grounded water pipe or to a pipe or metal rod driven four to eight feet in the ground. Radio ground pipes or rods should not be used for grounding any part of the electrical system.

PHASE - Phase as commonly used designates the type of power available, single phase or three phase. In most rural districts only single phase service is available for residential and farm service up to 5 to 7½ h.p. motors. For large power, three-phase service is necessary. A three phase motor cannot be operated on single phase.

TRANSFORMER - An electrical device which changes the pressure or voltage. For example, a transformer serving a farmer might "step-down" the voltage from 4,800 volts to 115 volts, or a bell-ringing transformer "step-down" 115 volts to 2½ to 6 volts.

ELECTRICAL CODES AND UNDERWRITERS LABORATORIES (See References) - The National Electrical Code, prepared by the National Fire Protection Association and the National Electrical Safety Code Handbook prepared by the Bureau of Standards, set forth, from a safety standpoint, the materials that may be used and practices to be followed in wiring to insure greater protection to life and property. ALL WIRING SHOULD MEET THE REQUIREMENTS OF THESE CODES as well as any local ordinances that may be in effect. The Underwriters Laboratories is maintained by the National Board of Fire Underwriters for testing electrical supplies and equipment. The results are made known through published lists of devices, appliances and materials which have been examined and approved. The use of approved materials and devices is important in order to reduce the hazard of fire and accident to a minimum and enjoy the best service.

UNITS, ABBREVIATIONS, AND SYMBOLS

Term	Practical Unit	Abbreviation	Symbol
Current	ampere	amp.	I
Electro-motive force (e.m.f.)	volt	volt	E
Resistance	ohm	ohm	R
Electric Power	watt or kilowatt	watt or kw.	P
Electric Energy	watt-hour, or kilowatt-hour	watt-hr. or kw-hr.	W
Mechanical Power	horse power	hp.	P
Mechanical Energy	horse-power-hour	hp-hr.	W
Work	foot-pound	ft.-lb.	W
Heat	British thermal unit	B.t.u.	Q

EQUIVALENTS.

1 hp.	= 550 ft.-lb. per sec., or 33,000 ft. lb. per min., or 745.6 watts
1 hp.-hr.	= 745.6 watt-hr., or 1,980,000 ft.-lb., or 2545 B.t.u.
1 kw.	= 1000 watts, or 44,256.7 ft.-lb. per min. or 1,341 hp.
1 kw.-hr.	= 1000 watt-hr., or 2,655,000 ft.-lb., or 1.34 hp. hr., or 3413 B.t.u.
1 B.t.u.	= 778.1 ft.-lb. or 0.293 watt-hr.

APPLICATIONS

1. What is the current in amperes required by a 50-watt, 115 volt electric lamp?
2. What is the current in amperes required by a 115-volt water heating element having a resistance of 20 ohms?
3. How long must the element operate in order to heat 10 gal. of water from 70° F. to 140° F.? For this purpose 5845 B.t.u. are required.
4. A bearing heats because of improper adjustment and lubrication. For each B.t.u. of heat thus liberated how many ft.-lb. of work are expended? This is equivalent to how many watt-hr.?
5. Determine the total consumption of electrical energy for each of the following, during the time designated.
 - (a) Six 40-watt lamps burning 4 hours daily for 30 days.
 - (b) A radio requiring 50 watts and operating for 3 hours per day, 30 days per month.
 - (c) A water system requiring 285 watts and operating 2 hours per day for 30 days.

REFERENCES

- "National Electrical Code for Electric Wiring and Apparatus" - Price 10¢. Copies may be secured by writing or calling at the Office of the Middle Department Rating Association of the Underwriters Association as follows:- 1100 - 13th Ave., Altoona, Pa.; Marine Bank Bldg., Erie, Pa.; Telegraph Bldg., Harrisburg, Pa.; Commonwealth Bldg., Pittsburgh, Pa.; Newrose Bldg., Pittston, Pa.; Masonic Temple Bldg., Ridgway, Pa.; 143 West 4th St., Williamsport, Pa.; 401 Walnut St., Philadelphia, Pa.
- "National Electrical Safety Code Handbook" - Bureau of Standards, Washington D.C. - Price \$1.00. Superintendent of Documents, Washington, D. C.
- Fire Underwriters Laboratories Inc., 109 Leonard St., New York City, N. Y. Communicate with this Organization for list of inspected electrical appliances.
- "Wiring the Farm", C.R.E.A. Bulletin, Vol. V, No. 1, published by the Committee on the Relation of Electricity to Agriculture, 1120 Garland Bldg., Chicago, Ill. Price 50¢. This is a book Vocational Schools should possess. Liberal use of materials and drawings in this Bulletin have been made in the preparation of the subject material in this circular.
- "Elementary Electricity" by Terrell Croft.
- "Electric Wiring for the Farm" - Cornell Bulletin No. 404.
- "Wiring Simplified" by Montgomery Ward.

WIRE MANUFACTURERS OR DISTRIBUTORS

Some of the following large manufacturers or distributors of copper wire may supply specimens of different sizes:

American Steel & Wire Co., Chicago, Ill.
Anaconda Wire and Cable Co., 23 Broadway, New York, N.Y.
Belden Manufacturing Co., 4673 W. Van Bueran Ave., Chicago, Ill.
General Cable Corporation, Rome, N.Y.
General Electric Supply Corporation, Philadelphia, Pa.
Graybar Electric Co., Philadelphia, Pa.
Hazard Wire Works, Wilkes-Barre, Pa.
John A. Roebling & Son, Trenton, N.J.
Westinghouse Supply Co., Philadelphia, Pa.

GENERAL PRECAUTIONS TO BE OBSERVED

1. When renewing fuses in a live or "hot" circuit, use one hand only and always stand on a dry board or other insulating material. IF POSSIBLE, FIRST PULL THE SWITCH AHEAD OF THE FUSE.
2. When using a trouble lamp, never allow the hands or finger to touch bare contacts. Keep them on the insulated wire or handles.
3. Never allow the body to become a part of an electric circuit; that is, from hand to hand or from hand or head to the feet. The current tends to flow from one wire to another or to ground. Avoid becoming a conductor.
4. NEVER DO REPAIR WORK ON A LIVE CIRCUIT. First open the circuit switch and remove the circuit fuses. Always consider all electric circuits "alive" until you have "killed" them yourself and positively know they are "dead".
5. Never work with an electrical circuit or handle an electrical appliance when standing on wet ground or wet floors or when in water.
6. If a shock is received from an appliance or motor, the cause should be determined at once and remedied.

PROBLEM II

READING THE RECORDING WATT-HOUR METER

Related Questions for Discussion

1. Why should one be able to read the meter?
2. How does one read the meter?
3. In what unit does the meter record?
4. How do you calculate the cost of the energy consumed during the month?
5. Will a mistake in one month's reading of the meter affect the total amount recorded over a period of time?
6. Will such a mistake affect the cost of the electrical energy purchased over (a) the month preceding the reading, (b) the month following the reading, and (c) a period including several months before and after the reading?
7. How can the electrical power requirements of a motor, heater, or any other electrical equipment be determined with the recording watt-hour meter?
8. How can the cost of operating a lamp or other equipment be estimated by the use of name-plate data?
9. Compare volt, ampere, watt, watt-hour, kilowatt and kilowatt-hour to gal. per min., pounds per sq. in. pressure; and other mechanical units.
10. Give the correct symbol for each of the above terms.
11. Does the common electric meter record electrical energy accurately?
12. If for any cause you wish to have the accuracy of the meter checked, who might be called upon to do this?
13. How will partial grounds and short circuits affect the kilowatt-hour meter reading? Why?

INFORMATION

The recording watt-hour meter is a device which records the electrical energy consumed over a period of time.

In the common type of meter, the recording apparatus is composed of a motor and a series of registering dials which are operated by a train of gears. The motor is propelled by the flow of electrical energy that is consumed by lamps, motors, and other appliances connected to the circuit. The rate at which the motor will drive this train of gears and thereby record the energy consumed is governed by the number and kind of pieces of electrical apparatus connected to the system. The rotating parts are mounted on jewelled bearings, and these meters will record accurately within a fraction of one percent of the total amount of electrical energy consumed.

DIALS. The train of gears operating the pointers on the disks are so arranged that one revolution of the first dial causes $1/10$ of a revolution of the next succeeding dial and so on for each of the number of dials contained in the meter. These dials are divided so that one complete revolution of the first dial on the right will record 10 kw-hr., the second 100 kw-hr., the third 1000 kw-hr., and the fourth, the dial on the left, 10,000 kw-hr. In other words, each succeeding dial will record ten times the amount of energy recorded on the preceding dial.

MULTIPLIER. On some types of recording watt-hour meters, it is necessary to use a multiplier or constant to find the actual energy consumed. Therefore, to find the total amount of energy recorded on meters having multipliers or constants, it is necessary to multiply the readings of the dials by this number which is found marked on the face of the meter.

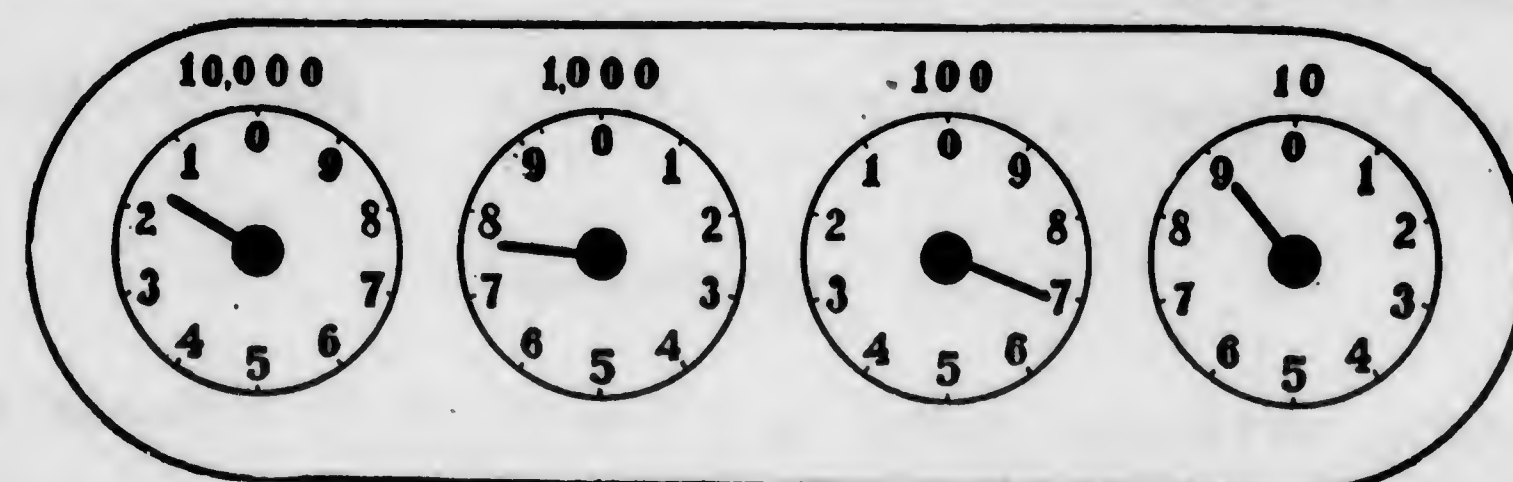
HOW TO READ A METER. Begin by reading the right hand dial and call each division 1 kw-hr. Proceed to the second dial and call each division on this dial 10 kw-hr. Likewise read the third and fourth dials in their order and term each division on the third dial 100 and those on the fourth dial 1000. These figures placed in proper sequence give the meter reading.

CAUTION. If the pointer falls between two divisions always read the smaller numeral because the pointer on the preceding dial must make one complete revolution before one division is indicated on the next dial. The only exception to this is in the case of the first dial, the reading of which may be estimated when the pointer falls between any two divisions.

The readings of the dials do not give the watt-hours used during the past month. To determine the number of kilowatt-hours used during a certain period, it is necessary to read the dials at the beginning of a period and again at the end of that period. By subtracting the first reading from the second, the number of kilowatt-hours used during the period is obtained.

EXAMPLE

The correct reading of the following diagram is 1769 kilowatt-hours:



CALCULATING THE COST OF ENERGY CONSUMED. In calculating the monthly bill it is necessary to know the number of kilowatt-hours of electrical energy consumed during the month and the power company's rate schedule. There are many types of rate schedules and many variations of each type. For this reason your power company representative should be consulted and costs calculated according to his directions. Tariffs are on file at the office of the local company and open for inspection upon request.

The unit cost of supplying residential and farm electric service becomes less as use increases, therefore, rates are made up so that the greater the use within a given demand, the lower the cost per kw-hr. They usually drop to a range of from $1\frac{1}{2}\%$ to 3% for general use in the low portion of the rate and to around 1% for off-peak water heating.

METER TESTING. The Public Service Commission at Harrisburg, Pa. maintains a meter testing laboratory as a section of its Engineering Bureau. This Laboratory has supervision over all public utility metering in the State. Its apparatus is checked periodically by the Bureau of Standards of Washington, D.C.

Under the law each utility is required to have its meter testing equipment tested and certified periodically by this Laboratory and pay a fee to the State for such test. The total of such fees covers the operating cost of the Laboratory. The utilities' meters as installed and maintained are tested periodically by this certified equipment. The rules require that each consumer's meter shall be tested at least once in every five years.

A consumer may obtain a test of his equipment open to observation by himself or anyone he may name, at any time between the scheduled tests, by paying a nominal fee to cover the cost of such test. If the meter is found to be inaccurate the fee is returned to the consumer; if the meter is found to be accurate within the limits of permissible tolerance, the fee is retained by the utility. A further direct check may be made by the testing laboratory in special cases. Complete information as to meter testing may be had upon application to the Testing Laboratory.

APPLICATIONS

1. Read the school meter.
2. Sketch meter dials and indicate the following readings:
(a) 1009 (b) 6835 (c) 6975 (d) 9099
3. If a man could do work at the rate of $1/10$ horse-power for a 10-hour day, how much is his labor worth as compared to the cost of operating an electric motor doing the same work? Assume the motor to be 80% efficient and the cost of electrical energy to be 5% per kw-hr.
4. How many kilowatt-hours will a 600-watt iron use in doing a 3-hour ironing? If the washer requires 280 watts how many kilowatt-hours will be used for a $1\frac{1}{2}$ -hour washing? What is the cost of operating each of these according to your local rate schedule?
5. Assuming a present use of 100 kw-hrs., how much would it increase the monthly bill to add an electric refrigerator using 50 kw-hrs. Assuming a present use of 100 kw-hrs., how much would it increase the monthly bill to add an electric range using 150 kw-hrs. per month. Water heating for residential purposes commonly requires from 300 to 600 kw-hrs. per month. What would 400 kw-hrs. cost on the water heating rate.

PROBLEM III

CONDUCTORS

Related Questions for Discussion

1. What is a conductor?
2. What is the difference between solid and stranded wire?
3. What is cable?
4. What is cord?
5. What is the difference between weather-proofed and rubber-covered wire?
6. What is bell wire and where may it be used?
7. What is fixture wire and where may it be used?
8. Why is wire made in different colors?
9. What is the purpose of the tracer found in cord?
10. How is the size of wire specified?
11. What is a wire gauge?
12. What is a circular mil?
13. What is the relation between the gauge number and the size of wire?
14. Why is it important to use the correct size of conductor?
15. What factors determine the correct size of conductor to use?
16. What is an electric circuit?
17. How may the wattage of a circuit be determined?
18. How may the amperage of a circuit be determined?
19. What is the minimum size of wire that should be used?

INFORMATION

Although aluminum, iron, and other materials are sometimes used for conductors of electrical energy copper is the element most extensively used. All the conductors used for ordinary building and farmstead lighting and power circuits are made of this metal. Many types or kinds of conductors are made from copper and these are insulated and covered in a variety of ways. Unfortunately the names of wiring materials are frequently confused and trade names are often used in place of the correct term. Because of this the following terminology is given for use in speaking of wiring materials.

WIRE. A slender rod or thread of metal made by drawing through dies.

INSULATED WIRE. A wire which is covered with insulation. (The term "wire" will be understood to include the insulation if used when circumstances indicate that the wire is insulated.)

SOLID WIRE. A slender rod or single thread of drawn metal.

STRANDED WIRE. A group of small wires not insulated from one another and used as a single wire. A small "cable", or, if properly insulated, a "cord."

CONDUCTOR. One or more wires not insulated from one another which are used for carrying an electric current.

STRANDED CONDUCTOR. A conductor composed of several or many wires.

STRAND. One or a group of the wires of a stranded conductor.

CABLE. A term sometimes applied to a solid wire heavily insulated and lead covered, but more generally meaning a stranded conductor (single-conductor cable) or two or more conductors insulated from one another (multiple-conductor cable). Although the term "cable" is usually applied to large sizes its meaning is general. Cables may be bare, insulated, or armored.

CORD. A small cable or stranded wire substantially insulated and very flexible.

Ordinarily conductors used for wiring buildings are of two general types; namely, WEATHER PROOF and RUBBER COVERED. In locations where wire or cable is exposed to the elements, weather proof insulation is used. This insulation consists of one or more cotton braids saturated with a weather resisting insulating compound. Rubber covered wire, or cable as the name implies, is insulated with rubber and covered with one or more cotton braids saturated with a moisture resisting compound. This type of conductor is always used for interior wiring.

CONDUCTOR SIZES

Conductor wires are made in various sizes which are usually designated by gauge numbers, the Brown & Sharp wire gauge (B. & S.) also known as the American Wire Gauge (A.W.G.) is used for this purpose. A number 12 wire is about the size of the lead in the average pencil while number 2 wire is about the same size as the pencil itself. Conductors of size number 8 and smaller are solid while all larger wires are stranded.

The cross-sectional areas of conductors larger than 4/0 are given in circular mils as a means of identifying their size. A CIRCULAR MIL is the area of a circle .001 inch in diameter. The cross-sectional area of a wire in circular mils is equal to its diameter in mils multiplied by its diameter in mils. One mil equals .001 of an inch. This method of expressing wire size is commonly used by engineers because of the ease with which it may be used in making calculations.

BRANCH CIRCUIT AND FEEDER WIRE SIZES FOR LOADING OF 5 AMPERES - 140 AMPERES FOR VARIOUS LENGTHS OF RUN*
Based on: Two per cent loss in voltage on 110 volt, 2-wire circuits. One per cent loss in voltage on 220 volt, 2-wire circuits. One per cent loss in voltage on 110/220 volt, 3-wire circuits.

LOAD IN WATTS	LENGTH OF RUN IN FEET															
	110 volt, 2-wire; 2-wire circuits	220 volt, 2-wire; or 110/220 volt, 3-wire circuits	LOAD IN AMPERES													
560	1100	5	14	14	14	14	14	14	14	14	14	14	14	14	14	14
660	1320	6	14	14	14	14	14	14	14	14	14	14	14	14	14	14
770	1540	7	14	14	14	14	14	14	14	14	14	14	14	14	14	14
880	1760	8	14	14	14	14	14	14	14	14	14	14	14	14	14	14
990	1980	9	14	14	14	14	14	14	14	14	14	14	14	14	14	14
1100	2200	10	14	14	14	14	14	14	14	14	14	14	14	14	14	14
1320	2640	12	14	14	14	14	14	14	14	14	14	14	14	14	14	14
1540	3080	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
1760	3520	16	14	14	14	14	14	14	14	14	14	14	14	14	14	14
1980	3960	18	14	14	14	14	14	14	14	14	14	14	14	14	14	14
2200	4400	20	14	14	14	14	14	14	14	14	14	14	14	14	14	14
2750	5500	25	10	10	10	10	10	10	10	10	10	10	10	10	10	10
3300	6600	30	8	8	8	8	8	8	8	8	8	8	8	8	8	8
3850	7700	35	8	8	8	8	8	8	8	8	8	8	8	8	8	8
4400	8800	40	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	9900	45	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	11000	50	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	13200	60	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	15400	70	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	17600	80	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	19800	90	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	22000	100	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	26400	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28600	130	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	30800	140	00	00	00	00	00	00	00	00	00	00	00	00	00	00

Note:- In order to prevent excessive loss in voltage, design feeders for a maximum of 1% voltage drop; branch circuits for a maximum of the 2% voltage drop. On short runs, where voltage drop does not affect wire size, the above table shows minimum permissible commercial size rubber covered copper wire according to the National Electrical code. Where wire larger than No. 10 is required to eliminate excessive voltage drop on branch circuits, limit the load to 600 watts, or move the panel board closer to the load center.

* Table based upon a tabulation made by the West Penn Power Company, Pittsburgh, Pennsylvania

The allowable maximum current to flow through a given conductor is limited by the heating of the wire which results in a loss of energy and deterioration of the insulation. Overloading not only causes the conductor to heat, but also causes a drop in line voltage which lowers the efficiency of the equipment being operated.

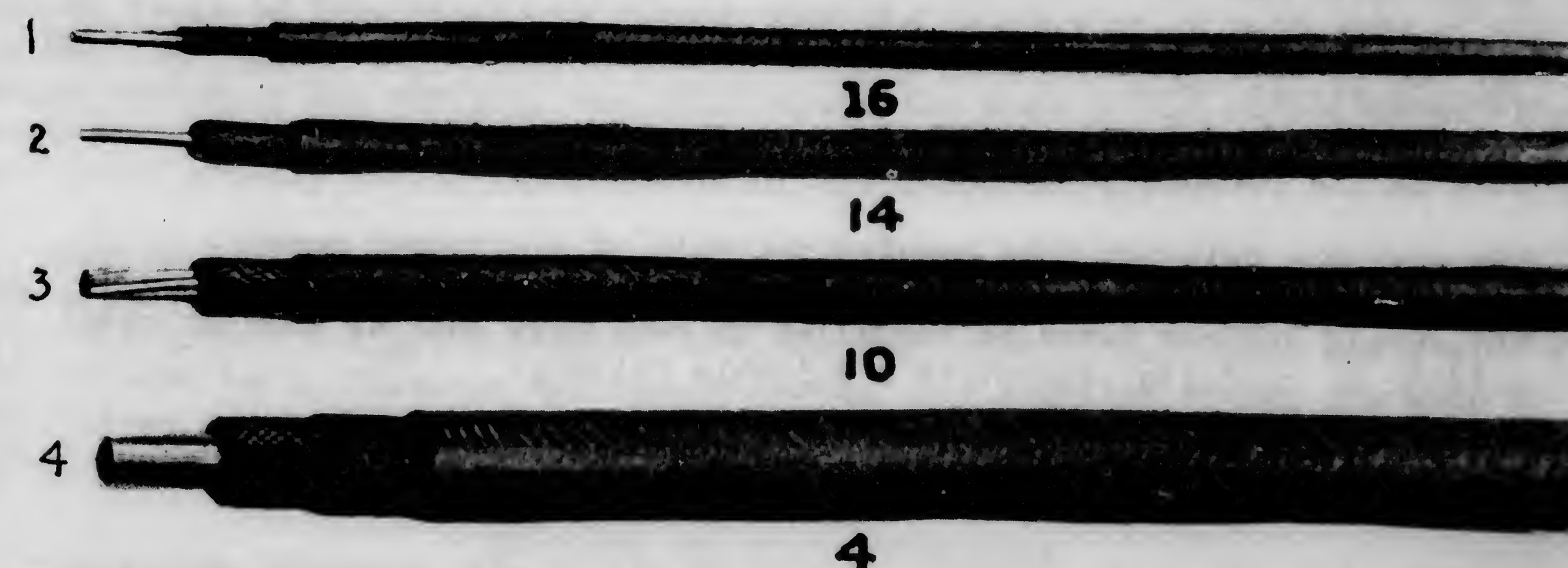
The proper size of insulated wire conductor for any circuit likely to be installed on the farm or in the home is given in the table on page 14. (An electric circuit is the path followed by electricity in flowing from a source through a conductor to one or more appliances through these and back through another conductor to the source.)

USE OF TABLE (Page 14). To determine the size of wire required first calculate the total load by adding the wattage of all appliances to be connected to the circuit, then locate this wattage in the column under the proper voltage; follow to the right on this line of the table until coming to the column giving the size of wire for the desired length of run.

No smaller wire than number 14 (B. & S.) should be used, except for wiring fixtures, or in flexible cords. Every conductor should be of proper size to give the desired voltage and mechanical strength for the conditions under which it is installed. The National Electric Code, city ordinances, and your power company regulations should be followed when choosing wire for use in making installations or repairs.

APPLICATIONS

1. Examine and learn to identify various wire, cord, and cable.
2. On a 115-volt, 2-wire circuit, carrying a load of four 25-watt lamps, six 40-watt lamps, and one 660-watt iron, what is the total wattage?
3. What size wire should be used in the above circuit when its length is:
(a) 40 feet, (b) 60 feet, (c) 100 feet, (d) 140 feet, (e) 240 feet, (f) 400 feet?



These wires are approximately actual size. The gauge number is below the wire in each case.

PROBLEM IV

SPLICING INSULATED WIRE AND CABLE

Related Questions for Discussion

1. Why is it necessary to splice a wire?
2. Why must the wire be thoroughly cleaned before splicing?
3. Should side cutting pliers be used in removing the insulation? Why?
4. What angle should the knife be held in respect to the wire when cutting away the insulation? Why?
5. What is meant by a splice being both mechanically and electrically secure?
6. Why must the connection be mechanically secure before soldering?
7. Why should the splice be soldered?
8. Why is flux used?
9. What kind of flux should be used?
10. How would you tin a soldering copper? Why?
11. If two wires are soldered with a flame instead of a soldering iron, why should the wire be placed in the flame instead of above it?
12. Why does the temperature of the wire have an important bearing on the effectiveness of soldering?
13. Why is it necessary to prevent air and moisture from contacting the wires in the finished splice?
14. What is the difference between rubber and friction tape? Which should be applied first? Why?
15. What is the purpose of the friction tape?
16. Why must the friction tape overlap the ends of the rubber tape?
17. Why should splices never be installed in race ways such as wood or metal molding or conduits, except at a suitable fitting?
18. When is it advisable to make the following splices? a. Western Union; b. T-splice; c. Pigtail; d. Y-splice; and e. wrapped or banded.
19. Why should splices in parallel conductors not be made opposite each other?
20. What precautions are necessary when splicing two different size wires?

INFORMATION

SPLICING SOLID WIRE

REMOVING THE INSULATION. Use a knife to cut the insulation, holding the blade at about a 30-degree angle to the wire. Care should be exercised when stripping insulation to prevent nicking the wire which will decrease its strength and cause it to break when it is twisted in the splice. After the insulation has been removed the wire should be scraped with the back of the knife blade to remove all oxide and little particles of rubber. This is not only important for good electrical contact but also prepares the surface for soldering. The splice must be **MECHANICALLY SECURE** to prevent pulling apart under ordinary strain, and **ELECTRICALLY SECURE** to be as good a conductor as the wire itself, therefore, five or six twists of the wire on both sides of the joint are necessary. The ends of the wire should be cut off and pressed tightly to the splice to prevent them from puncturing the insulation.

MAKING THE SPLICE. The splices are made according to the diagrams shown on page 18.

SOLDERING THE SPLICE. The purpose of soldering is to keep the joints secure and to minimize corrosion, thereby maintaining the conductivity of the splice throughout the life of the wire. When soldering the joints flux should be used to cause the solder to spread over and adhere to the wire. The flux used must not cause corrosion of the wire nor decomposition of the insulation. A paste flux or a flux contained in the solder wire is easiest to apply. Acid flux should never be used because it causes corrosion of the wire. The copper part of the soldering iron must be well tinned. Small wires may be soldered without the use of an iron by holding the joints in a flame. To prevent the wire from becoming oxidized and smoked it should be held in the flame rather than above it.

INSULATING THE SPLICE. Before applying tape remove all softened or injured insulation caused by the heat from soldering. The splice is next covered with one layer of rubber tape, overlapping each wrap to provide insulation equal to that of the original wire. In order to make the joint air and water tight several turns of tape should be placed over the insulation at both ends of the splice. The rubber tape should then be covered with friction tape in the same manner extending the wrapping one inch beyond the ends of the rubber tape. The friction tape prevents wear from abrasives. The size of the finished splice should not greatly exceed the diameter of the insulated wire.

USE OF SPLICES. (a) Western Union - Straight line splicing. (b) T-splice - When branch wire is attached to main wire. (c) Pigtail splice - In locations where the joints are not subjected to mechanical strain, and where space is limited such as in fixtures and outlet boxes. (d) Y-splice - When the ends of three wires are to be connected. (e) Wrapped or banded splice - In place of any of the other four types when large size solid wire is to be spliced.

SPLICING STRANDED CONDUCTORS

When making a splice in stranded wire or cable the insulation is first removed in the same manner as when splicing a solid wire. The strands must

then be untwisted and each one scraped bright in the same manner that the solid wire was cleaned. The two most common splices are shown in the diagrams. Each of the solid-wire splices described are applicable to stranded wire or cable with the exception that each must be wrapped separately. By following the diagrams any of these splices may be made.

APPLICATIONS

Make the following aplices:

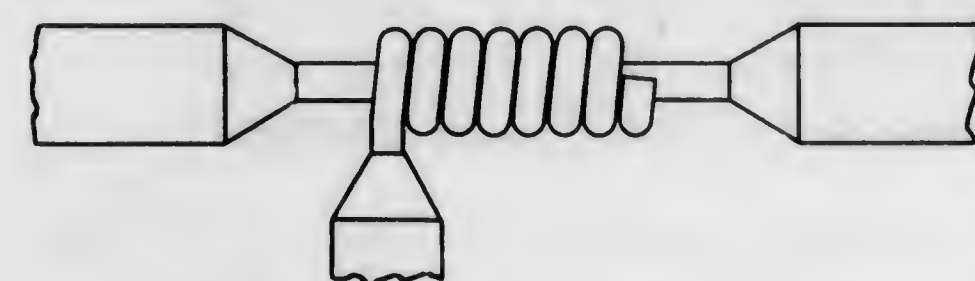
1. Western Union splice, using two No. 12 wires.
2. T-splice, using No. 10 and No. 12 wire.
3. Pigtail splice, using No. 14 and No. 16 fixture wire.
4. Y-splice, using two No. 12 wires and one No. 8.
5. Wrapped or banded splice, using two No. 8 wires, and No. 14 wire for wrapping.



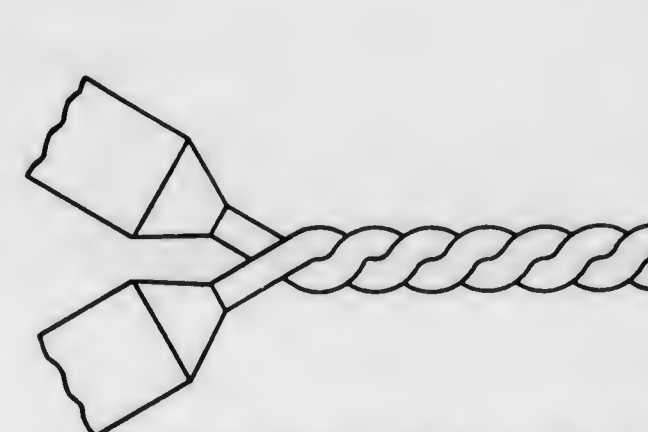
WESTERN UNION SPLICE



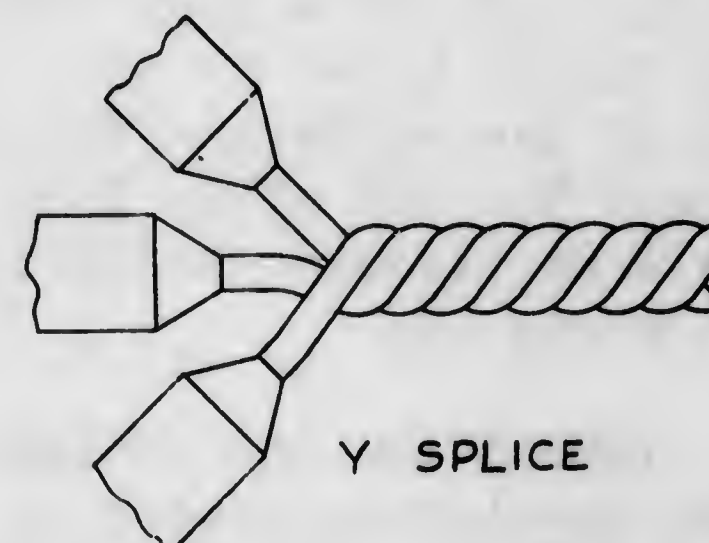
WRAPPED SPLICE



T SPLICE



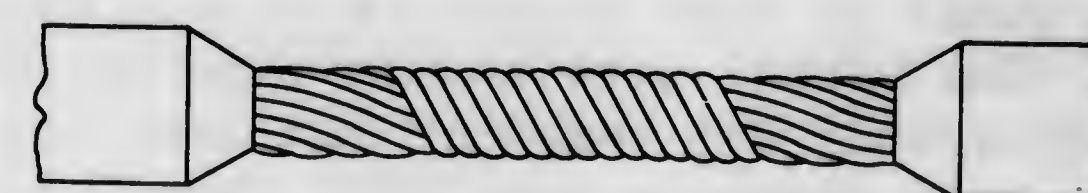
PIGTAIL SPLICE



Y SPLICE

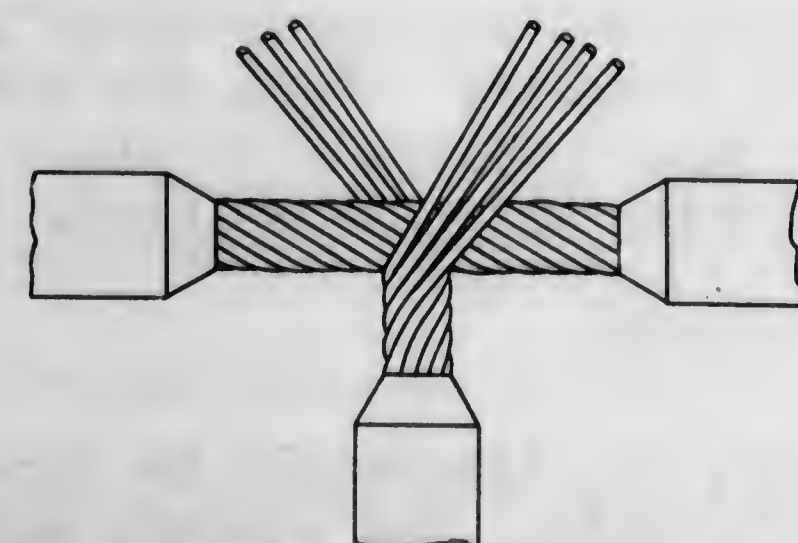


ENDS LACED TOGETHER

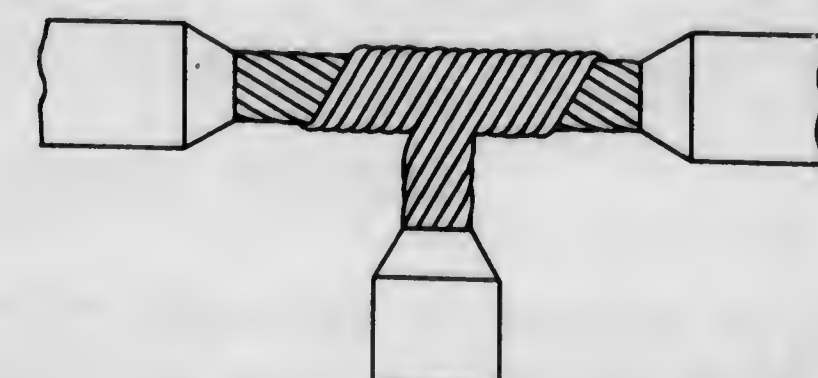


FINISHED SPLICE

SINGLE WRAP CABLE SPLICE



READY FOR SPLICING



FINISHED SPLICE

STRANDED WIRE T SPLICE

PROBLEM V

FUSES, OVERLOADS, AND SHORT CIRCUITS

Related Questions for Discussion

1. What are the devices used to protect a circuit against overloads?
2. What is meant by a short circuit?
3. What is a circuit?
4. What are some of the causes of short circuits?
5. What is an overload? How may it be determined?
6. What is likely to happen when two wires are short circuited? Why?
7. Can one protective device serve more than one circuit?
8. How can you locate a short circuit?
9. How do you make a test lamp?
10. Why is a weather-proof socket used?
11. Why should a 220-volt bulb be used in a test lamp?
12. What might happen if protective devices were omitted from the circuit? Why?
13. What is an open and closed circuit?
14. How can you detect a blown fuse or an open circuit?
15. If a new fuse is blown out the moment it is screwed into the receptacle, what is the trouble?
16. Why should a fuse be no larger than the capacity of the circuit that it feeds?
17. Why should pennies not be used for fuse substitutes?
18. Can overloads and short circuits be avoided in the home? How?
19. What is the recommended load for a branch circuit?

INFORMATION

THE PURPOSE OF PROTECTIVE DEVICES. There are several devices employed for protecting circuits and appliances against injury from overloads, accidental grounds, and short circuits. Although all these possess certain character-

istics which determine the use or application of each type, their important function is to limit the current flow to the safe capacity of the conductors through which the electrical energy is flowing. Overloading and consequent heating of a conductor not only causes a loss of electrical energy and inefficient operation of the appliances being operated, but also causes injury to the wire and insulation, starts fires, and endangers life. Every electrical circuit should be protected by a suitable device for breaking the circuit when an overload occurs thus preventing such damage and waste.

OVERLOADS, SHORT CIRCUITS, AND GROUNDS. An overload occurs when the rate of current-flow through a conductor exceeds its safe carrying capacity. This condition is often caused by connecting too many appliances to the circuit, or by using an appliance of a capacity too great for the wiring system. This is generally done through ignorance or carelessness.

When current flows by any path of relatively low resistance from one conductor to another or to the ground, as in the case of uninsulated portions of each of two conductors coming in contact with one another, a **SHORT CIRCUIT** is said to occur. **SHORT CIRCUITS** are caused by poor insulation, wet motors and other equipment, poorly spliced appliance cords, improperly connected service plugs and outlets, and other factors generally resulting from accidents or carelessness. The term "GROUND" implies that there is an electrical connection between a conductor and the earth. As the identified or neutral conductor of a circuit is grounded, a connection between the earth and an unidentified or "live" conductor will result in a short circuit.

OPERATION OF FUSES. The fuse is the most common device used for protecting wiring systems, although in some cases, circuit breakers, thermal cut-out switches, and others possess advantages. A FUSE is a short fusible-metal conductor generally supported by a protecting case or jacket and connected in the circuit by a fuse holder or cut-out. The fusible element or conductor is so designed that if the flow of current through the circuit, of which it is a part, exceeds a certain amount it will melt, thereby opening the circuit.

SELECTION OF FUSES. There are several types of fuses. The kind and size selected for a given use should be approved by the National Electric Code and also by local ordinances or rules should such exist. There is a proper size fuse for every circuit. The allowable carrying capacity of a combination lighting and appliance circuit of No. 14 rubber insulated wire is 15 amperes or 1630 watts, and a 15 ampere fuse is required. However, it is accepted good practice to limit the load on such a circuit to 1000 watts.

Both cartridge and plug-type fuses are used in farm wiring installations. Owing to the ease with which the plug type may be replaced by an unskilled person this type is commonly used in homes for circuits having a carrying capacity of 30 amperes or less.

IDENTIFYING OVERLOADS AND SHORT CIRCUITS. On a properly fused circuit, overloads and short circuits will cause the fuse element to melt thereby breaking the circuit. A fuse thus broken is said to be burned out or blown. Whether or not a circuit is overloaded may be determined by adding together the wattages of all lamps and appliances connected to the circuit and comparing the total with the allowable capacity of the wire and fuse. If the circuit is found not to be overloaded, then a short circuit exists.

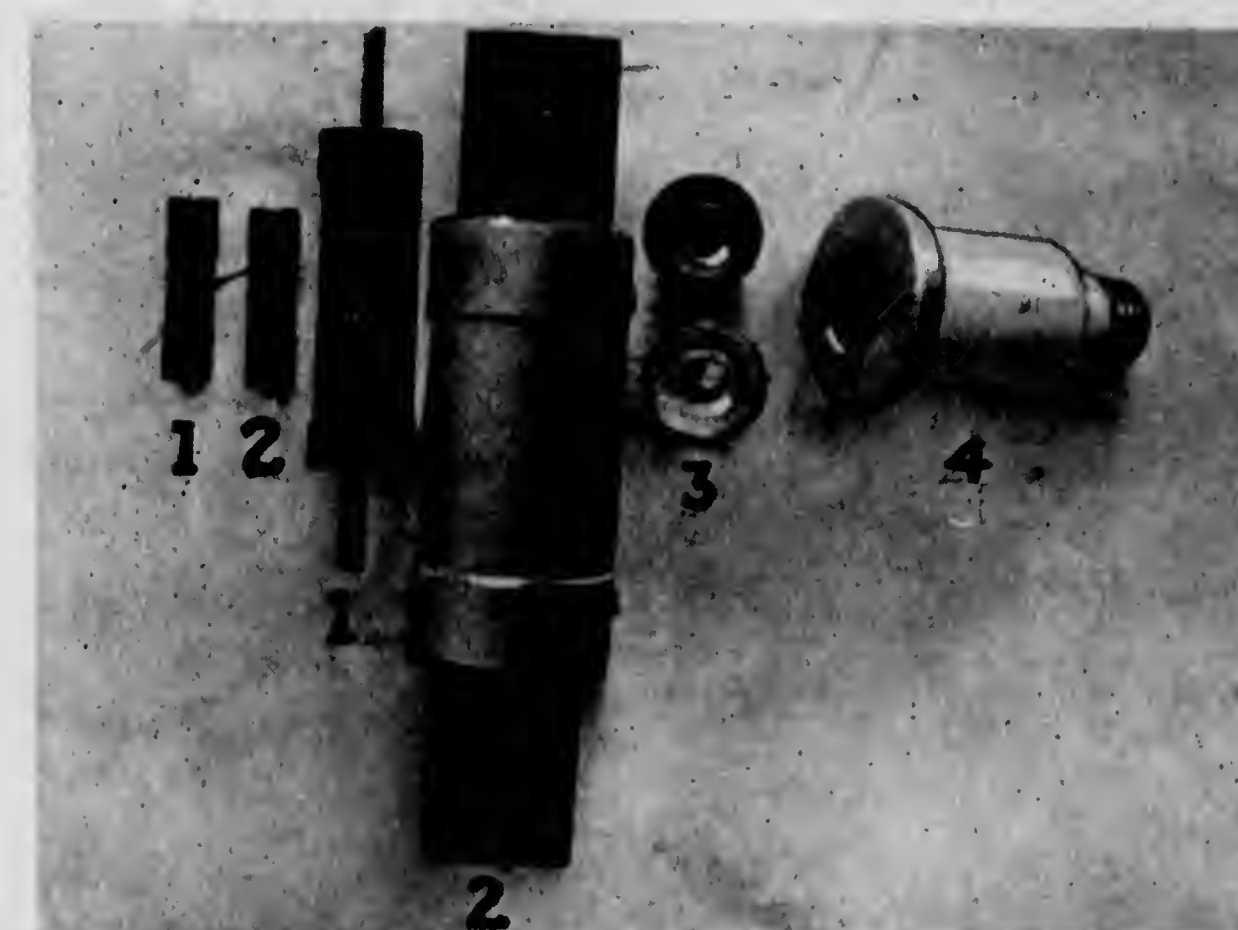
IDENTIFYING A BLOWN FUSE. The failure of lights and appliances to operate is generally due to one or more of the following troubles: - 1. One or more fuses blown due to overloads or short circuits; 2. the current being off; 3. One or more open connections due to broken or disconnected wire, a loosened switch contact, or a loosened fuse; 4. the mechanical or electrical failure of a light or an appliance.

If none of the lights and appliances will operate the trouble may be that the current is off; that the main entrance switch, the fuse or the wiring to the distribution panel is at fault or that the branch circuit fuses are blown.

When only the lights and appliances connect to one circuit fail to operate, the fuses for that circuit should first be checked. If a blown fuse cannot be detected by its appearance, it may be tried in another circuit in place of a fuse known to be good. Burned-out fuses should not be replaced without first correcting the cause of the trouble. Also the switch on the line side of the fuse should always be opened before a fuse is removed or replaced. Never bridge fuse outlets with pennies, wire, etc., nor use fuses with higher current ratings than that for which the circuit was designed.

APPLICATIONS

1. Determine the load on the circuits in your home or school.
2. Locate a blown fuse.
3. Replace the link in a renewable type cartridge or enclosed fuse.



Common Types of Fuses. (1) The reloading type of cartridge fuse. This fuse may be reloaded when it blows and may be loaded with links rating from one ampere up to the current limit of the contacts. It may be purchased in either the clip or blade design and is made to operate at 250 volts or less. (2) The common type of cartridge fuse. This fuse is the same as No. 1 except that it cannot be reloaded when it blows. (3) The common type of plug fuse. This fuse screws into a so-called Edison or standard screw base and rates from 1 to 30 amperes at pressures of 125 volts single phase. (4) A special

type of reloading link motor fuse called a thermal cutout. This fuse screws into a special cutout base in the motor cabinet. Every small motor on an automatic pumping unit should be protected by this type of fuse. Its time limit characteristics make it possible to fuse the motor close enough to its operating requirements to protect against burning out as it is not affected by the momentary overloads at starting. Unless a double throw switch is used ordinary fuses cannot be used to protect a motor.

PROBLEM VI

WIRING METHODS

Related Questions for Discussion

1. What are the various methods of wiring?
2. Where may each be used?
3. What are the advantages of each over the other?
4. Why must outside wiring be different from that done on the inside?
5. What precautions must be taken in wiring damp places?
6. Where should switches, convenience outlets, and bracket outlets be located?
7. What is meant by polarized wiring?
8. Why should additions to old installations be polarized?
9. When should a fuse or circuit breaker be installed?
10. Should open wiring be protected from mechanical injury? When and where?
11. How may open wiring be protected?
12. What type of wiring should be employed when it may be subjected to acid or corrosive fumes? In dry places?
13. What precaution should be taken in installing threaded conduit pipe?
14. Why should joints in underground pipe be made water tight?
15. How and where should any wiring system be grounded?
16. What are the advantages of grounding the system?
17. What precautions should be observed when cutting armored cable?
18. How and when are wires installed in pipe?

INFORMATION

WIRING METHODS. The four general methods of wiring interior areas are: 1. Conduit or pipe; 2. Non-metallic and metallic sheathed cable; 3. Knob and tube; and 4. Surface wiring using moulding.

CONDUIT. The conduit system of wiring (See illustration B on page 23) consists of the installation of conduit pipe and specially designed fittings to connect the source of energy with the equipment being operated. Wires are drawn or "fished" into the raceway thus obtained. When installing the conduit the ends must be reamed, and when two pieces are joined they should butt to-

gether in the coupling so as to provide a smooth continuous raceway to receive the wires. When bends are made, care must be taken to prevent kinks or depressions from occurring in the walls of the conduit which will decrease its cross-sectional area and hinder pulling the insulated wires into the conduit. The conductors installed should be spliced only at suitable fittings or outlet boxes and a splice should never be pulled into the conduit. The conduit should be properly grounded and thus form a continuous electrical shield over the complete circuit.

The **IRON CONDUIT SYSTEM** is used in areas where the wiring is likely to be subjected to mechanical injury, fumes or liquids detrimental to wire and insulation. This system allows wires to be concealed in masonry, concrete, and underground construction. Accessibility of the wires at all times in case of trouble is another advantage of this system. Its cost, however, is greater than that of any other type of wiring.

METALLIC SHEATHED CABLE. Metallic sheathed cable or armored cable consists of two or more insulated wires encased in steel armor and attached to outlet boxes by suitable bushings thus giving continuous protection to the wire over the entire circuit. This type of wiring may be used where it will be subjected to mechanical injuries, but not in locations where harmful fumes and dampness exist.



Flexible Armored Cable



Illustration B

Conduit and cable require several fittings to attach them to outlet boxes, switch boxes, etc. The common rigid conduit fittings are illustrated above. (1) Service head or power service outlet. A weather head must turn down 45° to prevent water running into the conduit through the wire holes in the head. (2) Rigid conduit. This is a specially treated iron pipe. It comes in ten foot lengths and may be used with screw or threadless fittings. (3) Pull box elbows which serve to change the conduit direction as well as to make easier the pulling-in of the wires. (4) Common fittings such as bushings, reducers, clamps, etc. (5) Metal straps which are used to attach the conduit and cable to the walls and ceiling.

Armored cable can be used for either surface or concealed wiring (See illustration A on page 23). It is difficult to do a neat job with armored cable when wiring over flat surfaces, especially ceilings, in which case the supporting clamps must be placed closer together in order to prevent sagging of the cable. Ordinary pipe clamps nailed or screwed in place may be used for this purpose. In the case of concealed wiring the cable may be supported by drawing through holes bored in the rafters, studs, joists, or other timbers.

In no case should the cable be bent sharply enough to separate the overlapped steel tape which serves as the armor. Care should be taken not to injure the insulation when cutting the armor. Also, bushings should be used to cover the sharp ends of the armor after it is cut in order to safeguard against these edges puncturing the insulation and causing short circuits.

Cable bearing a white wire to be connected to the grounded side of the circuit should be used. In case the grounded side must be connected to a black wire its visible ends should be painted white to make identification possible. The armor should make electrical contact with all outlet boxes and should be grounded.

NON-METALLIC SHEATHED CABLE. Non-metallic sheathed cable consists of two or more wires encased in a moisture resisting fibrous covering. This cable is used in much the same manner as armored cable, being attached directly to the surface with pipe clamps and installed in areas protected from moisture. It withstands the corrosive action of stable fumes and is therefore well adapted for wiring barns.

Non-metallic sheathed cable must be protected from mechanical injury. This is done by placing guard strips on both sides of the cable where ever there is any possible chance for it to be injured. To eliminate the risk of mechanical injury the cable should be located in the corner formed by the ceiling and wall when conditions make it practical to do so.

KNOB AND TUBE. The knob and tube system of wiring consists of insulated conductors supported by porcelain knobs or other non-combustible insulating materials. In cases where the conductors pass through wood, masonry, or other obstructions, or where they contact the surface of these materials or other wires, they are insulated with porcelain tubes or a non-metallic sheathing as an additional precaution. Although the conductors are of insulated wire they are treated as if they were bare, never being allowed to come near any surface without being further insulated.

This type of wiring may be either "open" or installed in partitions and beneath floors. Spliced conductors may be located in partitions or where ever desired; this is not the case with other types of enclosed wiring. However, outlet boxes should be used with this type of wiring as well as with the others, and open wiring should be protected against mechanical injury. This is the oldest and generally the cheapest method used in wiring dry interior areas and is extensively used for wiring homes.

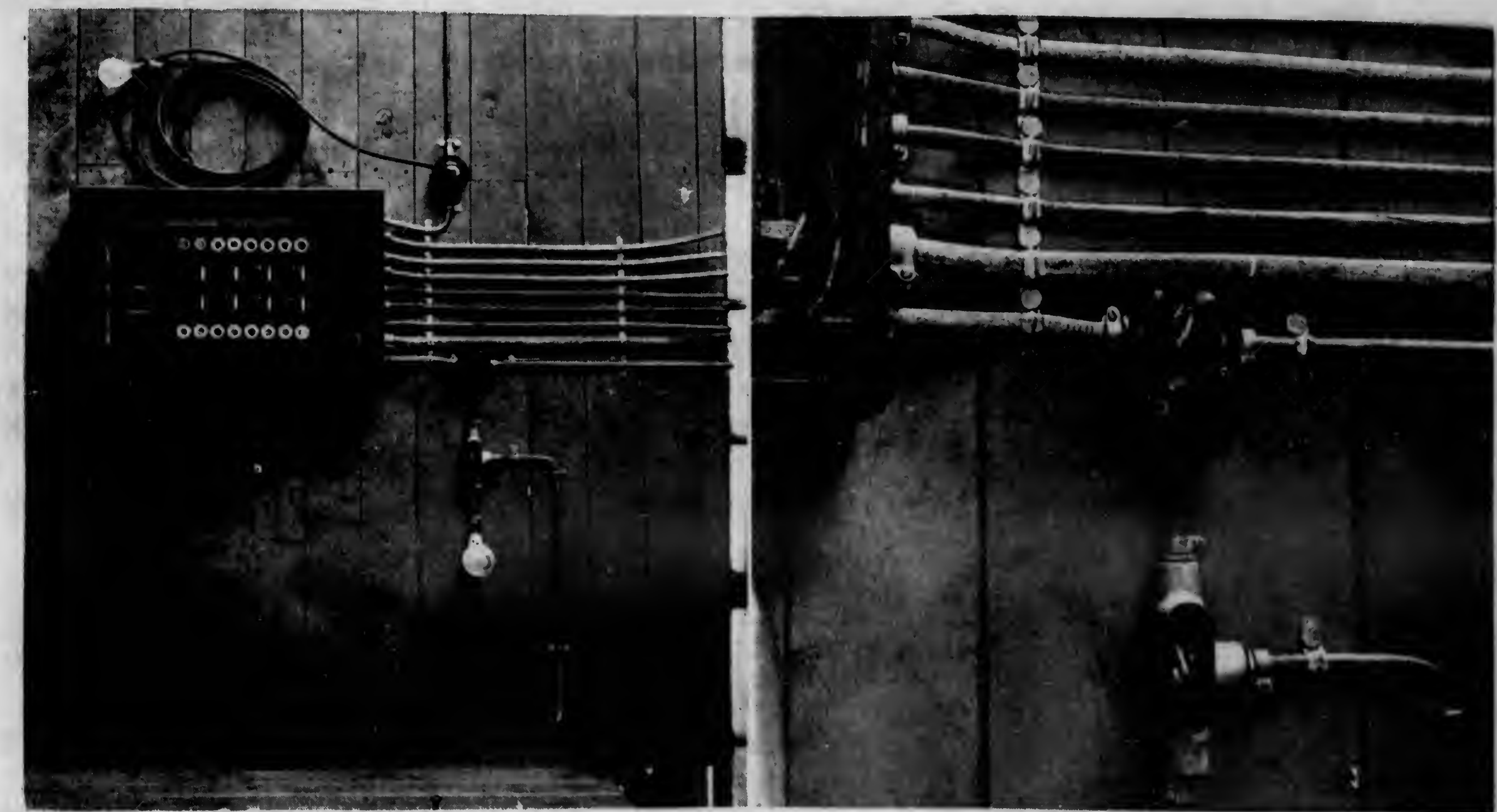
MOLDING. Of the two kinds of molding, wooden and metal, it is better to use the metal type as it is much safer and better appearing. Metal molding consists of a raceway composed of a channel and capping, suitable fittings and outlet boxes into which two or three insulated wires may be placed. When install-

ing this type of wiring, care must be taken in making splices and protecting the insulation from being damaged by sharp edges. In general, the same precautions should be observed as when installing a conduit pipe system.

Molding is generally used in making extensions to existing wiring systems in places where surface wiring must be used and a neat appearing job is desired. It is suitable for use in dry locations since it provides good protection to the wires and makes a neat installation.

POLARIZED WIRING. In any wiring system it is important that one conductor be "grounded" and identified as the ground wire. This is accomplished by grounding one of the conductors at the transformer and again at the service distribution panel. Wire having white insulation or bearing a tracer, which may consist of a red or other colored thread in the covering, is used throughout the wiring system for this grounded or neutral size of the circuit. This identified wire should in no case be broken at any point between the point of entrance and the last outlet on the circuit. Switches should always be installed in the unidentified or "live" side of the circuit.

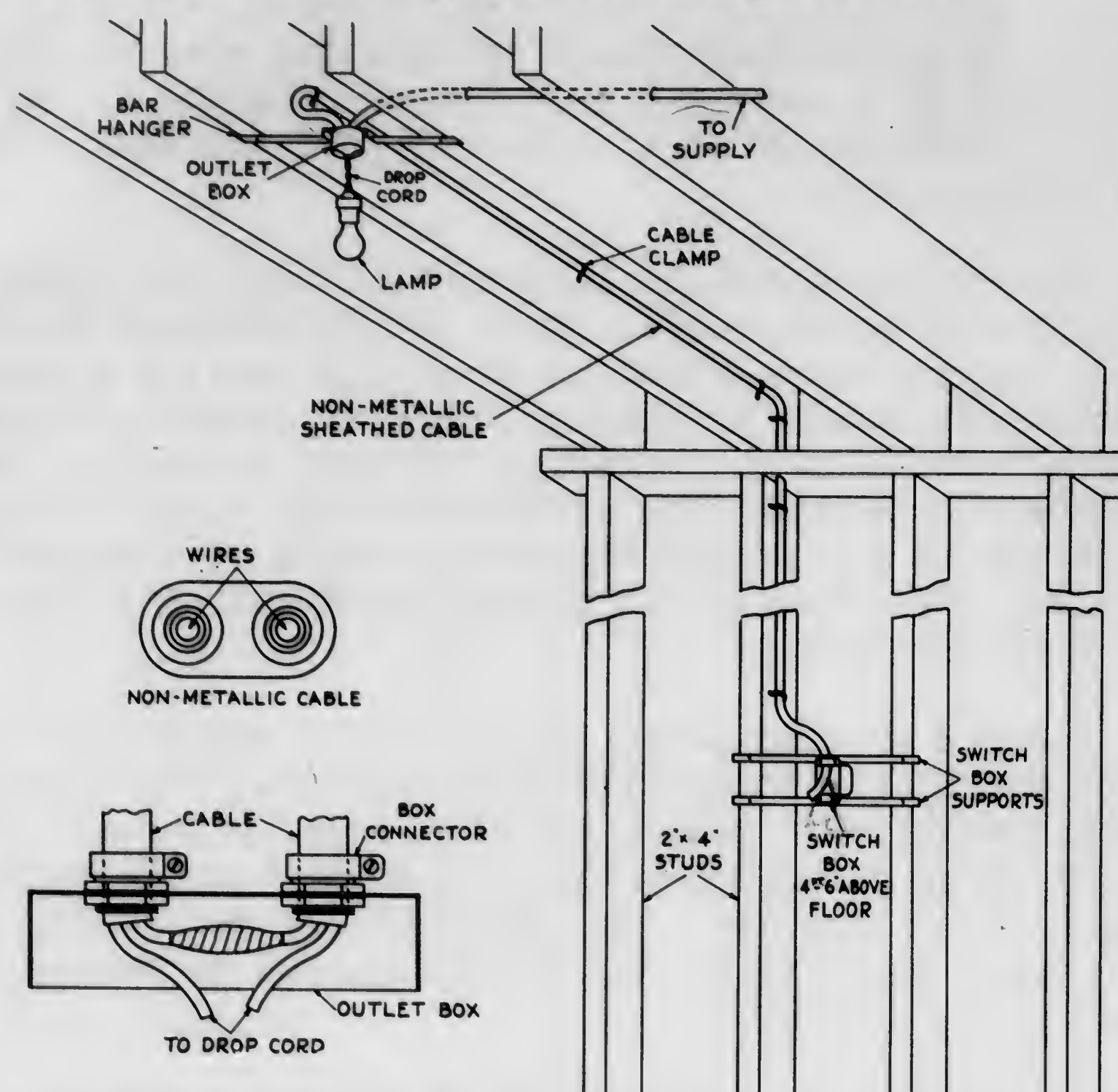
When fixtures such as sockets are connected to the wiring system the screw shell should always be connected to the identified wire or cord. The terminal to be connected to the identified wire is generally "tin" colored and the other terminal "brass" colored. Wires of different colors, or those bearing different tracers should never be spliced together. The National Electric Code, city ordinances and your power company regulations should be followed in making any additions or changes to the wiring system.



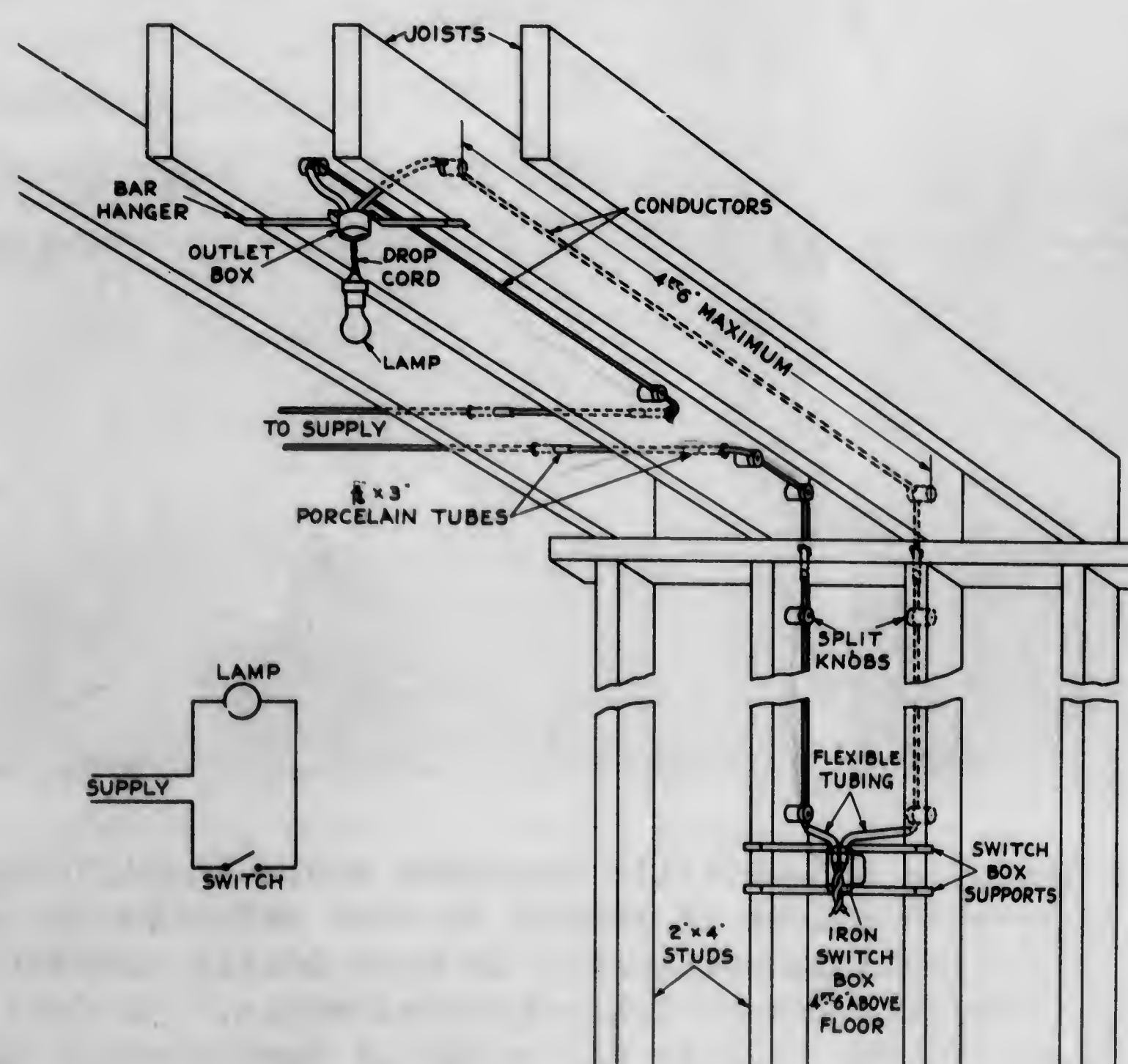
General and close-up views of a non-metallic sheathed cable installation. By running the cable along protected places it should be very satisfactory for barn wiring as the product of reliable manufacturers is more nearly moisture and fume proof than any other material except lead sheathed cable. In fact it should be entirely satisfactory for practically all types of farm wiring, except when located where it would be subject to mechanical injury.

APPLICATIONS

1. Install one drop cord light, using knob and tube wiring as shown by the following sketch.



2. Install a switch to control the drop light, using non-metallic sheathed cable.



MATERIALS

- 1 porcelain keyless socket
- 6 porcelain naillet knobs
- Tape, solder and paste
- 4 ft. No. 14 non-metallic sheathed cable
- 1 fuseless rosette
- 10 ft. No. 14 rubber covered single braid wire
- 10 in. No. 16 reinforced lamp cord
- 2 - $3\frac{1}{4}$ " octagonal outlet boxes with $\frac{1}{2}$ " knock-outs.
- 1 - 5 ampere switch cover
- 1 - 5 ampere, 125-volt indicating snap switch
- 1 blank cover for $3\frac{1}{4}$ " octagonal outlet box
- 2 ft. flexible tubing
- 6 - 1" No. 8 flat head wood screws

PROBLEM VII

INSTALLING AND REPLACING PLUGS AND SOCKETS

Related Questions for Discussion

1. Where are plugs and sockets commonly used?
2. Why should every home have one or more extension cords?
3. What are the recommended lengths of extension and portable lamp cords?
4. What are the advantages and disadvantages of portable lamps?
5. Why should lamp guards be used on extension cords?
6. What are the common causes for failure of plugs and sockets?
7. Where is the cord likely to break first? Why?
8. Why should the strands of flexible wire be well twisted before attaching to the binding screws?
9. How is a supporting knot tied in Flexible core? For what purpose?
10. What substitutes may be made for the knot?
11. What would happen if the uninsulated wires should come in contact with each other?
12. Why should the ends of the wire always point in the direction in which the binding screw is tightened?
13. What precautions should be taken when preparing cords for connecting to plugs, sockets and rosettes?
14. Are the connecting screws the same color? Why?
15. Which terminal is connected to the screw shell of the socket?
16. To which terminal should the wire bearing the "tracer" be connected?
17. What are the various types of sockets and where should each be used?
18. Why is a socket bushing required in all metal sockets?
19. What type of socket should be used on an extension cord?
20. What is the function of the fibre lining in brass shelled sockets?
21. Why should like colored wires always be spliced together?
22. Should one attempt to connect a permanent drop cord to a live circuit?

23. What kind of cords should be chosen for appliances such as bridge lamps, trouble lamps and toasters?

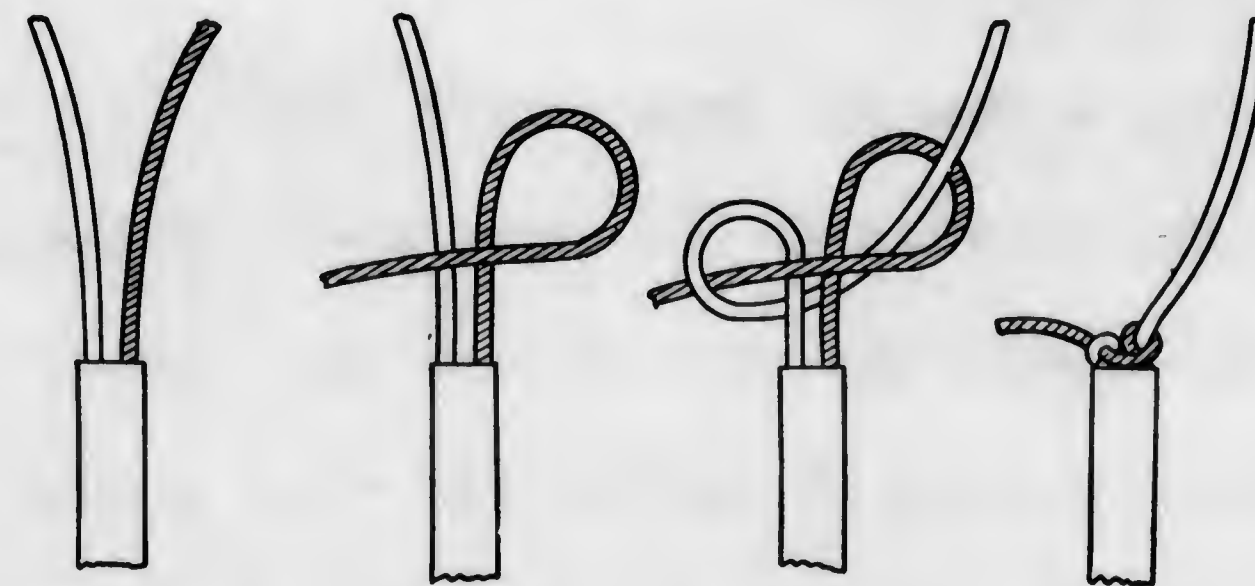
24. In order to reduce the possibility of trouble with appliances, what care should be given them?

INFORMATION

CAUSES OF CORD AND APPLIANCE FAILURES. Appliances such as floor lamps, toasters and trouble lamps become injured mainly from improper use and careless handling. Mechanical injuries may be caused by dropping the plugs and sockets, stepping on them, pulling on the cord to disconnect the plug and crushing, cutting or burning the cord. Electrical failures are generally caused by overloads and sometimes by short circuits.

MATERIALS. It is recommended that portable lamps be wired with cord not smaller than No. 16, the carrying capacity of which should not exceed 6 amperes. Sockets and plugs also are designed for specific loads. Wire and fittings should never be subjected to loads greater than those for which they are designed because of the resulting decrease in life of the apparatus, decrease in efficiency and increase in fire hazard. All materials and fittings purchased should be of a make approved by the National Electric Code.

INSTALLING PLUGS AND SOCKETS. When installing either a plug or a socket the ends of the wires should be cut off so as to remove the broken or frayed portion. The insulation should then be removed, observing the same precautions as when removing the insulation in making a splice. In order to remove all possible strain from the binding screws the Underwriter's holding knot should be used in the fitting. How to tie this knot is shown in the accompanying illustration. Tape may be used in place of the knot.



How to Tie the Underwriter's Holding Knot

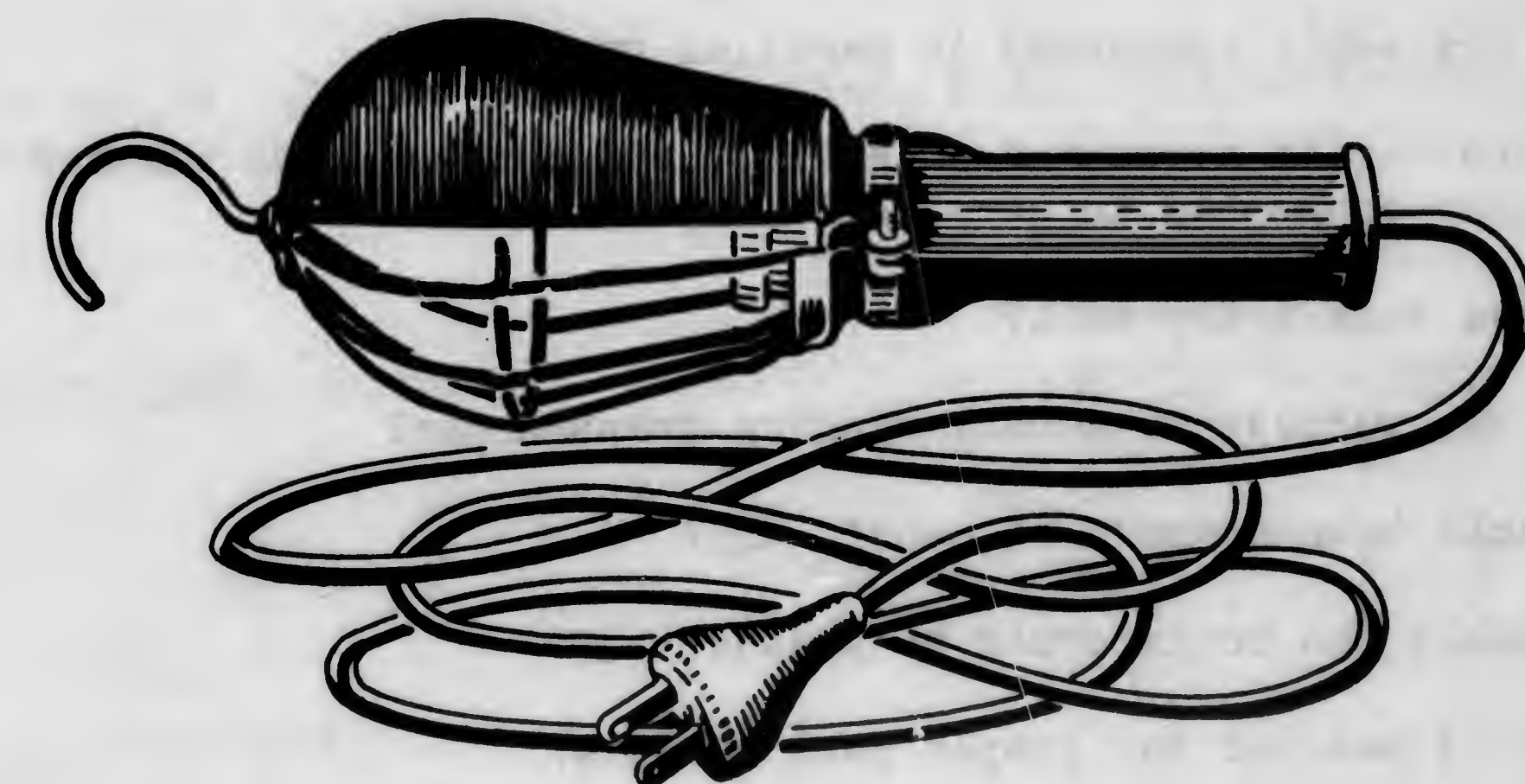
Wires should be wrapped clockwise about the binding screws to aid in securely fastening each strand. A bushing should always be used in metal fittings to protect the wire insulation from being cut by the sharp edges of the shell. Spliced wire should never be passed through a conduit.

PERMANENT DROP CORDS AND FIXTURES. Sockets are replaced on permanent lights in the same manner as on portable lamps with the exception that they are connected so as to keep the wiring system polarized. Where a rosette is used to support the drop cord and lamp, a fire underwriters' knot or tape should be used to prevent any strain on the binding screws.

APPLICATIONS

A. Make a drop light - Materials: 12" of reenforced cord No. 16; 1 - 3/8" keyless socket; 1 - 2 wire fuseless rosette.

B. Make an extension cord - Materials: 1 - extension cord handle and guard complete with socket; 1 - attachment cap with strain guard.



EXTENSION CORD AND GUARD

PROBLEM VIII

WIRING A TWO-BATTERY BELL CIRCUIT

Related Questions for Discussion

1. What is the principle of the electric bell?
2. What kind of wire should be used for electric bell work? Why?
3. If the wires which terminate at the bell, battery or push button were shorted what would happen?
4. If two or more dry cells are used, how would you connect them together?
5. Can a simple circuit bell be controlled by two-push buttons? How?
6. What is meant by parallel connection?
7. When is it necessary to have a parallel circuit buzzer? Why?
8. How can a one-bell simple circuit buzzer be changed into a two bell parallel circuit controlled by two switches?
9. If a bell did not ring from either switch where would you look for the trouble?
10. Why are dry cells used?
11. How are dry cells connected in parallel or series?
12. Would three cells connected in series have more or less voltage than the same number connected in parallel? Why?
13. How do you test a dry cell?
14. What is the purpose of a bell-ringing transformer?
15. When should transformers be used? Why?
16. Where should the transformer be placed?
17. What use is made of the simple bell circuit?
18. Is a push button necessary? Why?
19. How shall the bell wires be supported?
20. Should both wires be fastened with the same staple? Why?
21. Should the staples be insulated? Why?
22. What precautions should be taken when running bell wires through floors? Why?

23. Is it desirable to solder joints made in bell wire? Why?

24. How do you calculate the voltage of a battery composed of a number of dry cells hooked either in parallel or series?

25. Where should push buttons be located? Why?

INFORMATION

CONSTRUCTING THE BELL CIRCUIT. Locate the push button and bell, and provide the necessary openings for passing the wires through walls or partitions. Run two parallel wires from the bell to the push button, connecting the wires to each. Cut one of the wires at the battery location and connect the battery.

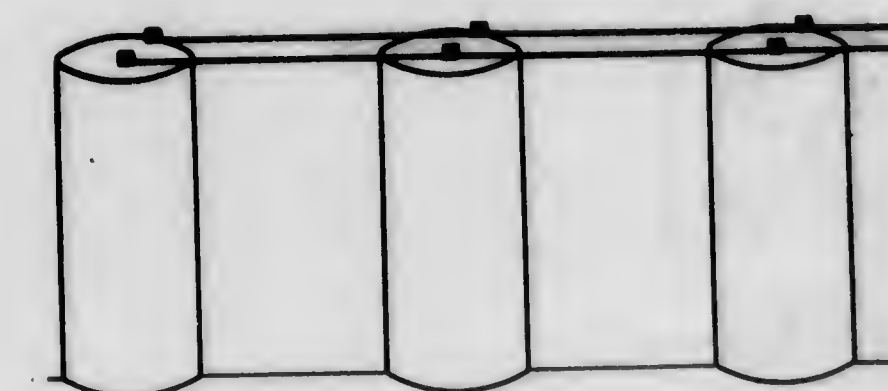
USE OF TRANSFORMER. If a 115-volt current is used to supply energy for the bell, it will be necessary to install a bell ringing transformer to reduce the voltage to a point which can be conveniently used for bell circuit wiring, usually $2\frac{1}{2}$ to 6 volts. The primary side of the transformer should be connected to the lighting circuit and the secondary side to the bell circuit. The transformer should be protected by a fuse inserted between the lighting circuit and the transformer.

APPLICATIONS

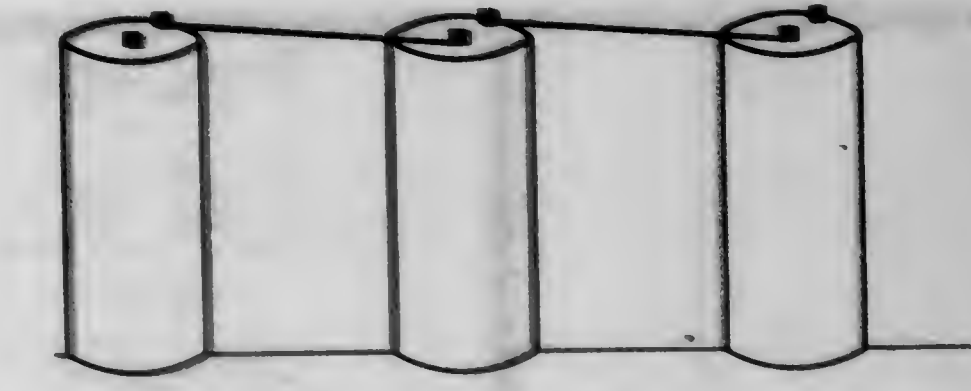
1. Wire a single bell and push button battery circuit.
2. Wire a single bell and push button transformer circuit.

MATERIALS

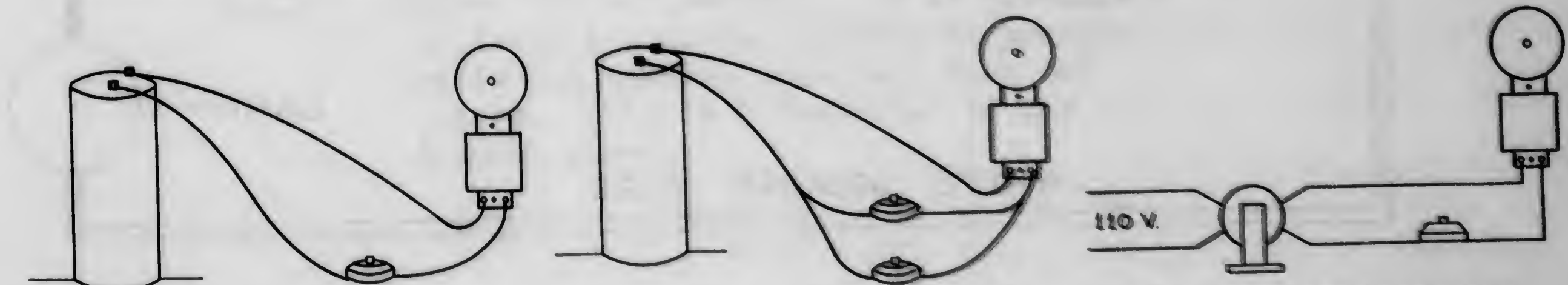
20 ft. No. 18 bell wire; 1 push button; 2 dry cell batteries; 1 electric $2\frac{1}{2}$ inch vibrating $2\frac{1}{2}$ volt bell; transformer.



CELLS IN PARALLEL



CELLS IN SERIES



BELL AND BUTTON

BELL AND TWO BUTTONS

BELL AND TRANSFORMER

PROBLEM IX

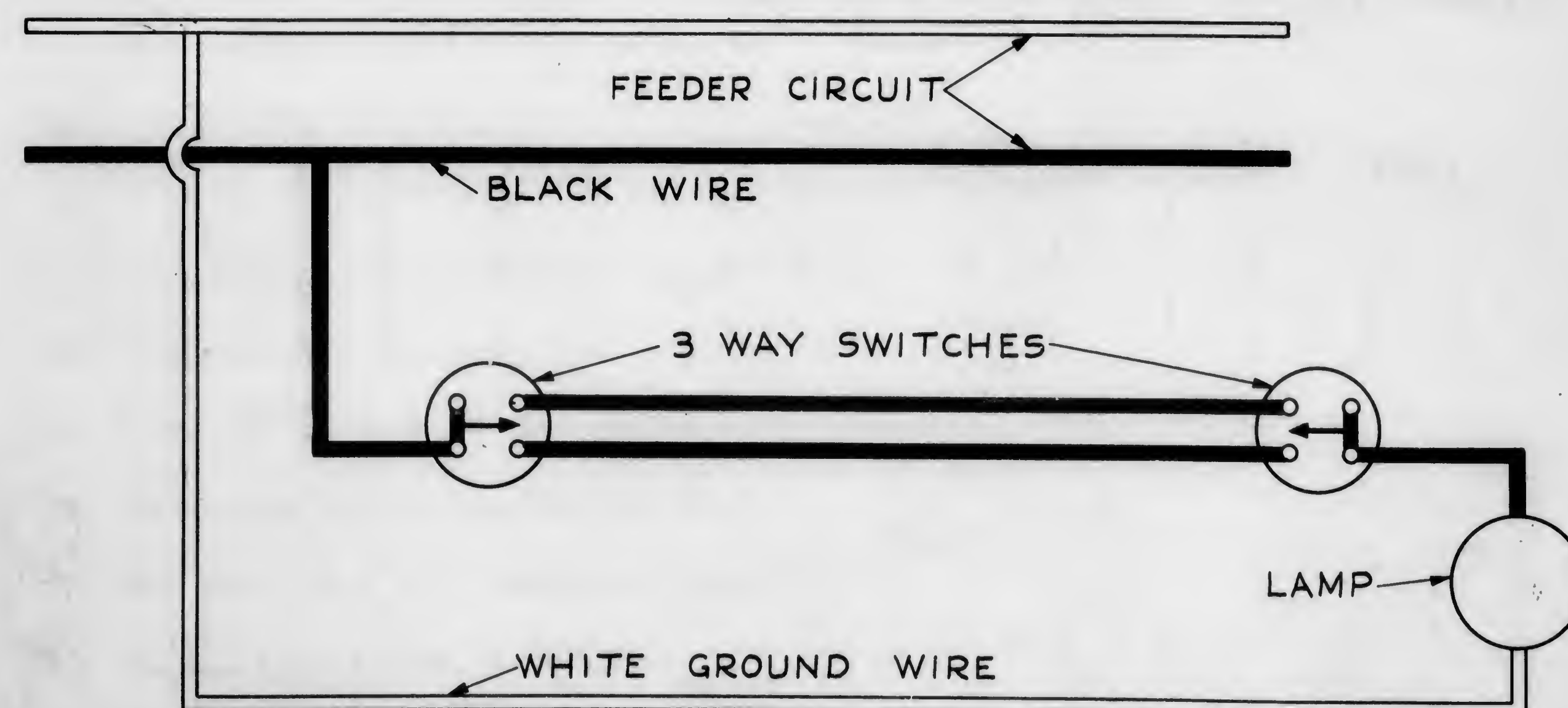
WIRING THREE-WAY SWITCHES

Related Questions for Discussion

1. What uses may be made of an outlet controlled at two points?
2. What are the different types of switches to be used?
3. How many wires must be connected to each switch? Why?
4. Why is the ground wire never connected to the switch?
5. Where should the switches be located?
6. How should both the ground and live wire be designated?
7. What precautions should be observed in using any of the wiring methods?

INFORMATION

It is often desirable to have a light or apparatus controlled from two points independent from each other. This is accomplished by using two three-way switches, locating them at two convenient points.



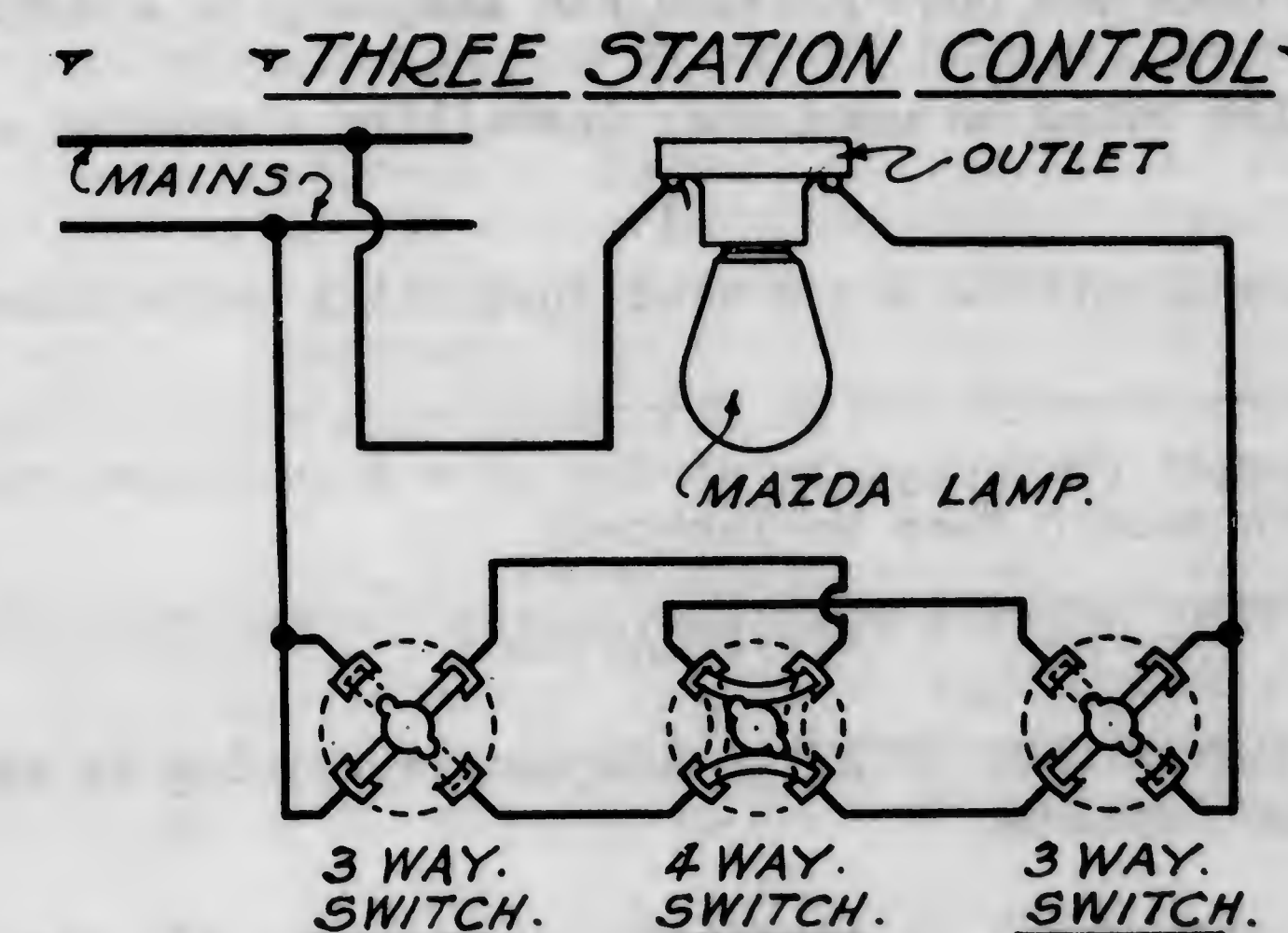
3 WAY SWITCH WIRING DIAGRAM

WIRING THE CIRCUIT. The white wire is connected to the ground side of the feeder circuit and to the ground terminal of the light or apparatus being connected. Two black wires are run between the two switches and connected as shown in the diagram. The bridged terminal of one switch are then connected to the line wire of the feeder circuit, and the similar terminals of the other switch to the appliance, using black wires to make the connection. The switches are connected on the black or line wire so that when either switch is operated the ground or identified wire will not be broken.

APPLICATIONS

1. Construct a three-way switch circuit as indicated by the diagram on the preceeding page.

MATERIALS - 25 amp., 125 volt, three-way surface snap switch; 25 amp. switch base for open wiring; 10 ft. No. 14 R.C.S.B. black wire; 3 ft. No. 14 R.C.S.B. white wire; 1 brushless rosette; 1 ft. No. 16 drop cord (2 conductor); and 1 - 3/8" keyless porcelain socket.



Three Station Control. It is possible to install a wiring circuit to provide switching control from more than two points. This is illustrated in the diagram above.

PROBLEM X

INSTALLING A CONVENIENCE OUTLET

Related Questions for Discussion

1. Why is adequacy of wiring important?
2. What are the advantages of convenience outlets?
3. Where should outlets be placed?
4. How can a convenience outlet be controlled by one or more switches?
5. Why should duplex outlets be installed instead of single outlets?
6. What factors determine whether or not a convenience outlet should be installed in any given circuit?
7. Why should the Code be followed when making additions to existing wiring?
8. Why should the polarization of the wiring system be maintained? See exercise - "Wiring Methods"
9. To what extent does the Code provide for adequacy in a wiring system?
10. Why should outlet boxes be used when installing convenience outlets flush in wall?
11. What precautions should be taken when installing convenience outlets in the floor?
12. In order to provide for adequate wiring of a farm house, what outlets are needed and where should they be located?

INFORMATION

INSTALLING A CONVENIENCE OUTLET. Adequacy in wiring is dependent upon three very important factors:

1. That the wiring size shall be large enough to carry all the electrical energy supplied.
2. That there shall be a sufficient number of branch circuits so that the load in lights or appliances shall not initially exceed 1000 watts per branch circuit.
3. That there shall be a sufficient number of outlets located within the building so that the furniture arrangement will be independent of the location of any electrical outlets and long lengths of extension cords to appliances, lamps, etc., will be eliminated.

Careful planning in the location of convenience outlets will provide outlets where work is to be done or an appliance attached and permit the use of shorter extension cords.

A rule of thumb method of locating these outlets in the residence is that there should be not less than one convenience outlet for each six feet of unbroken wall space. For barns and outbuildings there should be an outlet wherever a piece of electrical equipment will be used. In most instances, it is advantageous to locate the convenience outlets in the dwelling in the baseboard rather than in the plaster above it. The exception to this rule is in the location of certain outlets that serve appliances such as washers, ironers, and other heavy duty electrical current consuming devices.

It is sometimes found desirable to control convenience outlets with switches where certain lamps or other similar types of equipment are used. The advantage of switching them is to eliminate the necessity of retracing steps when a device is to be turned on or off. A further advantage is that outlets of this type may be controlled from two or more switch locations entirely independent of each other, i.e., they may be turned on from one station and turned off from another station entirely remote from the first. For instance, if we had a room in which there were two main entrances, it would be advantageous to locate switches controlling the outlets at either door.

While single convenience outlets may be installed, it is recommended that the duplex type be used, because two appliances may be directly connected to the duplex outlet instead of one.

The factors which determine to what particular circuit a convenience outlet may be connected when making additions to existing wiring are: - Size of wires of the branch circuit and the connected load of the circuit.

If we had a branch circuit consisting of two No. 14 wires feeding a load of some 1200 to 1500 watts, it would be undesirable to install a convenience outlet on this circuit. This is true because only a limited load can be connected to this outlet; therefore, the convenience outlet could not provide the maximum flexibility and capacity for which these outlets are primarily installed.

When installing additional convenience outlets on existing wiring systems, the National Electric Code should be followed because if the installation is in accordance with this Code, the wiring will be safe against hazards and provide an installation which is to all intent and purposes free from troublesome defects sometimes found in installations where this Code is not followed.

APPLICATIONS

To install a convenience outlet in a finished room.

1. Determine location for convenience outlet and using an outlet box placed flat against the baseboard, mark the outline for cutting.
2. With brace and bit bore two holes through the baseboard, one diagonally opposite the other in corners, exercising care that the hole does not show outside the edge of the outlet box.
3. With the aid of a hack saw blade cut along the outline and remove the cut out piece of wood.

4. Place the outlet box in position and install wires after removing the knockouts in the ends of the knockout box.

5. Connect and install the convenience receptacle and attach plate. Exercise care that the outlet box be recessed sufficiently to make the plate fit snugly against the baseboard.

MATERIALS. 1 - $2\frac{1}{8}$ " switch outlet box with loom knockouts; 1 - duplex convenience receptacle, T-slot type; 1 - pressed brass or composition convenience outlet plate; 4 ft. No. 14 single braid, r.c. wire; 2 nailt knobs; 10" of flexible tubing; 4 - $\frac{5}{4}$ ", No. 5 wood screws.



Some common types of outlets are shown above (A) Pendant convenience outlet. (B-1) Surface convenience outlet. (E) Double convenience outlet. Receptacles or outlets of the screw-shell type, are not permitted except for use as lamp holders. (D-1) A table plug with three convenience outlet taps. This must be used with discretion so as not to overload the circuit unless a separate circuit of adequate capacity has been put in to meet maximum demands.

**End of
Title**